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Discussion of "New Empirical Model for Breaching of Earth-Rock Dams" by Qiming Zhon, Shengshui Chen, Zhongzhi Fu and Yibo Shan

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Abstract

In this discussion, the authors will point out that even if Zhong et al. (2020) tackle an important problem, by ensuring the quality and credibility of the data recorded in the database presented and by providing the description of the used method to obtain their non-linear equations it certainly can improve their original study. Therefore, this discussion highlights the limitations and shortcoming to the study presented by Zhong et al. (2020) original paper.

1 Introduction

Overall, in the original paper, Zhong et al. (2020) have combined seven databases in order to obtain a worldwide database allowing them to deduce new empirical equations adapted for embankment dam failures. Thus, even if the authors mentioned that "the advantage of this new model is that the formulas have been developed based on a larger database of dam breach cases and the choice of the input parameters. The model performance and comparison with the existing empirical models testify to the rationality of the new model", this discussion demonstrates that in fact the model is not undoubtedly accurate.

Also, even if the authors considered that "the comparison cannot judge which model is better based on these dam breach cases—the intention is only to demonstrate that relatively large differences still exist in empirical dam breach models.", this discussion highlights a fundamental question which is: how much data is necessary to ensure that these dam breach cases could be neglected in this judgment?

2 Data quality and reliability validation

Zhong et al. (2020) used a database recording mostly Chinese dam failures. Indeed, a total of 84 case studies from China are recorded from the 162 data recorded (i.e. 52% of the compilation). After reviewing the 162 dam failures recorded by Zhong et al. (2020) it has been possible to highlight that 8 references listed are not properly cited (i.e. see case studies "id" in the original database of Zhong et al. (2020) : 97, 100, 104,105, 112, 138, 139 and 140) and various cases have nor been properly recorded (e.g. see case studies "id" in the original record : 22, 35, 50, 59, 75, 88, 91. 96, 103, 106, 107, 114, 116, 130, 136, 137, 161). Indeed, the major concern is the apparent absence of any auditing of data quality in the new dataset. In fact, notice that based on Zhong et al. (2020) compilation:

- The database recorded by Froehlich (2016) is not used in this compilation, even if it is the most used in practice. Also, the latest database now available (Bernard-Garcia and Mahdi, 2020) is also not listed in the original paper. This up-to-date database records a total of 3,851 dam failures case studies.

- A total of 5 case studies are recorded as man-made dam failure, but as recorded in the references cited 2 case studies refers to natural dam failures (i.e. see case studies id in the original database of Zhong et al. (2020) : 95, 140) and 3 case studies to laboratory test data (i.e. see case studies id in the original database of Zhong et al. (2020) : 41, 66, 95).
- One key breach parameter included in the new dataset is the peak discharge. However, there are a range of methods that are used to estimate this parameter yet there is no indication in the new dataset how it has been estimated in each case.
- The second key breach parameter included in this new dataset is the time failure which in the literature has various definitions, but no distinction or correction has been considered by the authors.

3 Identification of the used method for regression analysis

Zhong et al. (2020) didn't take the effect of the failure mode in their analysis. Since some of the dam breach parameters, such as the final breach form or its time of formation, are strongly related to the breach modes, the coefficients of the empirical proposed formula and its rationality should be discussed by the authors. Moreover, a distinction between the overtopping and seepage dam failure case studies will certainly lead to more representative equations and might improve the quality of the analysis proposed by the authors. Also, Zhong et al. (2020) should have used nondimensionalized equations to reduce the number of involved parameters and increase understanding of the problem (Singh and Quiroga, 1988).

Even though, in order to identify the method used by the authors, the regression analyzes proposed in this discussion follow the author's point of view. Thereby, knowing that the formulation of the three non-linear equations proposed by Zhong et al. (2020), i.e. equations 1 to 3 of the original paper, can be linearly resolved in order to deduce the exact solution of the system of equations, the discussers here assumed that this simple regression method was chosen by the authors, as presented below.

Non-linear equation form:

$$y_i = \left(\frac{V_w^{\frac{1}{3}}}{h_w}\right)^{b1} \cdot \left(\frac{h_w}{h_b}\right)^{b2} \cdot h_d^{b3} \cdot e^{b4} \quad \text{where} \quad y_i = \begin{cases} y_1 = \dfrac{Q_p}{V_w \cdot g^{\frac{1}{2}} \cdot h_w^{-\frac{1}{2}}} \\ y_2 = \dfrac{B_{ave}}{H_b} \\ y_3 = T_f \end{cases}$$

Linear equation form :

$$\log(y_i) = \boldsymbol{b_1} \cdot \log\left(\frac{V_w^{\frac{1}{3}}}{h_w}\right) + \boldsymbol{b_2} \cdot \log\left(\frac{h_w}{h_b}\right) + \boldsymbol{b_3} \cdot \log(h_d) + b_4 \cdot log(e)$$

$$where \;\; \boldsymbol{b_0} = b_4 \cdot \log\,(e)$$

The results obtained to identify the regression method used are presented in Figures 1 to 3. Thus, it is possible to highlight the non-consistency between the calibration coefficient obtained and compared to those presented by Zhong et al. (2020). Also, as illustrated in Figure 1 at least two cases have not been used by the authors, e.g. the two cases out of the domain obtained for the peak discharge equation. Therefore, explicitly specify how the calibration was obtained and the different hypotheses considered, in particular in the selection of the failure cases used, will help identify the limitations of the proposed equations.

4 Calibration of the equation using the new database currently available

In the same perspective, the form of the equations has been calibrated using the new database currently available in the literature (Bernard-Garcia and Mahdi, 2020). Figures 4 to 6 compare the results presented by Zhong et al. (2020) to those obtained using Bernard-Garcia and Mahdi (2020) database. Notice that these results were all obtained using the regression analysis tool available in the XLSTAT (Addinsoft, 2020). As illustrated in Figures 4 to 6, adding new case studies in fact impact the reliability of the equation obtained. Indeed, even if the results can seems “similar”/”coherent” regarding the differences in the regression equation obtained and the disparities identified, i.e. notably for the time failure parameter, it is beneficial for the readers to clarify and justify the domain of application of their study and correctness of their hypothesis.

Thus, it highlights the impact and the necessity of considering the case studies used during the regression analysis to ensure the quality and credibility of the predictive equation proposed. Moreover, as illustrated in Figure 7, the number of case studies certainly influence the regression equation obtained and it is still not possible to neglect the number and/or quality of the case studies records in this empirical process which contradict what was suggested by Zhong et al. (2020), i.e. “the comparison cannot judge which model is better based on these dam breach cases—the intention is only to demonstrate that relatively large differences still exist in empirical dam breach models”.

5 Conclusion

The results presented in this discussion highlight that in fact the credibility of the recorded data, as well as the number of cases studies, impacts the results and needed to be first considered in order to ensure the reliability of the presented equations by Zhong et al. (2020). Indeed, the unreliability of the information recorded in their database, also as the incomplete references cited and used to combine the previous databases in their work have certainly limited the rationality of the new equations developed by Zhong et al. (2020). Overall, the shortcomings and questions highlighted about the correctness of the interpretation/analysis of the data needs to be clarified by Zhong et al. (2020) to provide an accurate portrait of their study.

ACKNOWLEGMENTS

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List of Figures

Adapted from Zhong et al. (2020) original paper

Homogeneous dams (HD) :

$$\frac{Q_p}{V_w \cdot g^{\frac{1}{2}} \cdot h_w^{-\frac{1}{2}}} = \left(\frac{V_w^{\frac{1}{3}}}{h_w}\right)^{-1.58} \cdot \left(\frac{h_w}{h_b}\right)^{-0.76} \cdot h_d^{0.1} \cdot e^{-4.55}$$

Corewall dams (CD) :

$$\frac{Q_p}{V_w \cdot g^{\frac{1}{2}} \cdot h_w^{-\frac{1}{2}}} = \left(\frac{V_w^{\frac{1}{3}}}{h_w}\right)^{-1.51} \cdot \left(\frac{h_w}{h_b}\right)^{-1.09} \cdot h_d^{-0.12} \cdot e^{-3.61}$$

Recalculated from Zhong et al. (2020) database

Homogeneous dams (HD) :

$$\frac{Q_p}{V_w \cdot g^{\frac{1}{2}} \cdot h_w^{-\frac{1}{2}}} = \left(\frac{V_w^{\frac{1}{3}}}{h_w}\right)^{-1.64} \cdot \left(\frac{h_w}{h_b}\right)^{-1.24} \cdot h_d^{-0.001} \cdot e^{-4.24}$$

Corewall dams (CD) :

$$\frac{Q_p}{V_w \cdot g^{\frac{1}{2}} \cdot h_w^{-\frac{1}{2}}} = \left(\frac{V_w^{\frac{1}{3}}}{h_w}\right)^{-1.37} \cdot \left(\frac{h_w}{h_b}\right)^{-5.68} \cdot h_d^{-0.68} \cdot e^{-2.46}$$

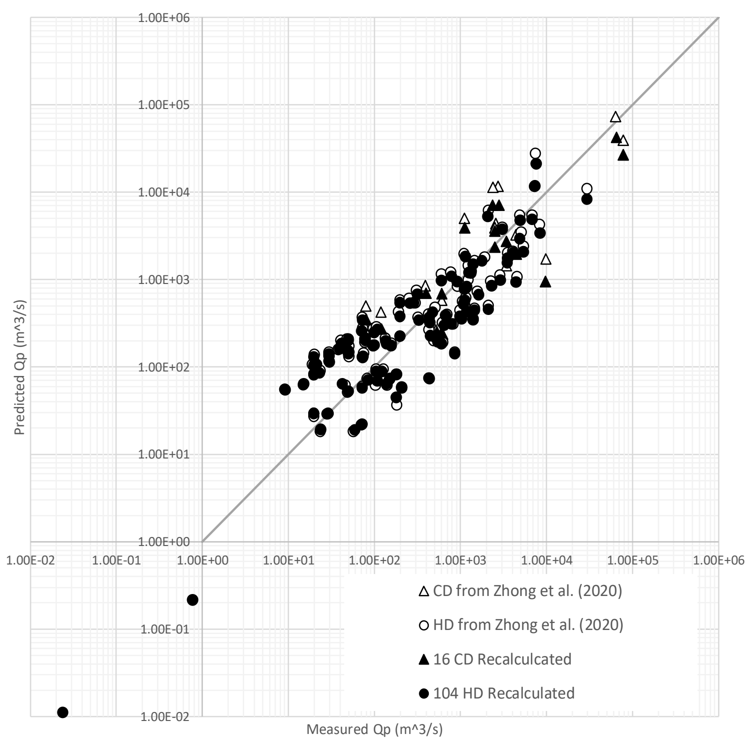

Figure 1 : Comparison of measured and predicted Peak discharge (Qp) for breached earthrock dams adapted from Zhong et al. (2020) database

Adapted from Zhong et al. (2020) original paper

Homogeneous dams (HD) :

$$\frac{B_{ave}}{H_b} = \left(\frac{V_w^{\frac{1}{3}}}{h_w}\right)^{0.84} \cdot \left(\frac{h_w}{h_b}\right)^{2.3} \cdot h_d^{0.06} \cdot e^{-0.9}$$

Corewall dams (CD) :

$$\frac{B_{ave}}{H_b} = \left(\frac{V_w^{\frac{1}{3}}}{h_w}\right)^{0.55} \cdot \left(\frac{h_w}{h_b}\right)^{1.97} \cdot h_d^{-0.07} \cdot e^{-0.09}$$

Recalculated from Zhong et al. (2020) database

Homogeneous dams (HD) :

$$\frac{B_{ave}}{H_b} = \left(\frac{V_w^{\frac{1}{3}}}{h_w}\right)^{0.77} \cdot \left(\frac{h_w}{h_b}\right)^{2.01} \cdot h_d^{0.14} \cdot e^{-0.94}$$

Corewall dams (CD) :

$$\frac{B_{ave}}{H_b} = \left(\frac{V_w^{\frac{1}{3}}}{h_w}\right)^{0.67} \cdot \left(\frac{h_w}{h_b}\right)^{1.66} \cdot h_d^{-0.08} \cdot e^{-0.12}$$

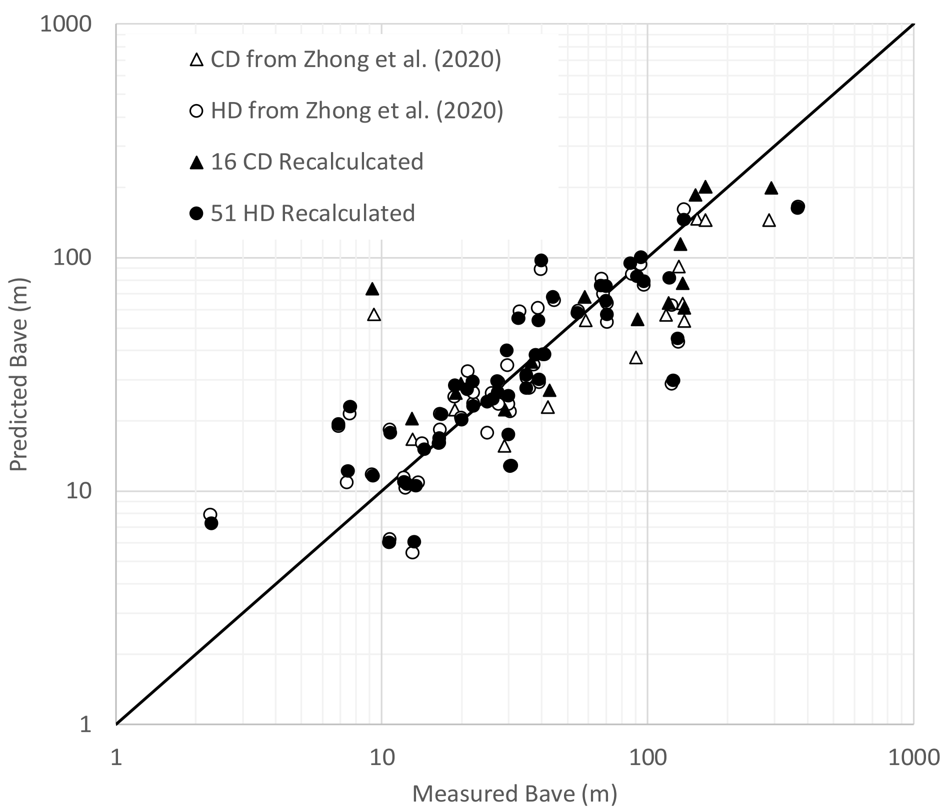

Figure 2 : Comparison of measured and predicted Breach average width (Bave) for breached earth-rock dams adapted from Zhong et al. (2020) database.

Adapted from Zhong et al. (2020) original paper

Homogeneous dams (HD) :

$$T_f = \left(\frac{V_w^{\frac{1}{3}}}{h_w}\right)^{0.56} \cdot \left(\frac{h_w}{h_b}\right)^{-0.85} \cdot h_d^{-0.32} \cdot e^{-0.2}$$

Corewall dams (CD) :

$$T_f = \left(\frac{V_w^{\frac{1}{3}}}{h_w}\right)^{1.52} \cdot \left(\frac{h_w}{h_b}\right)^{-11.36} \cdot h_d^{-0.43} \cdot e^{-1.57}$$

Recalculated from Zhong et al. (2020) database

Homogeneous dams (HD) :

$$T_f = \left(\frac{V_w^{\frac{1}{3}}}{h_w}\right)^{0.56} \cdot \left(\frac{h_w}{h_b}\right)^{-0.61} \cdot h_d^{-0.5} \cdot e^{0.31}$$

Corewall dams (CD) :

$$T_f = \left(\frac{V_w^{\frac{1}{3}}}{h_w}\right)^{1.82} \cdot \left(\frac{h_w}{h_b}\right)^{-7.05} \cdot h_d^{-0.1} \cdot e^{-3.53}$$

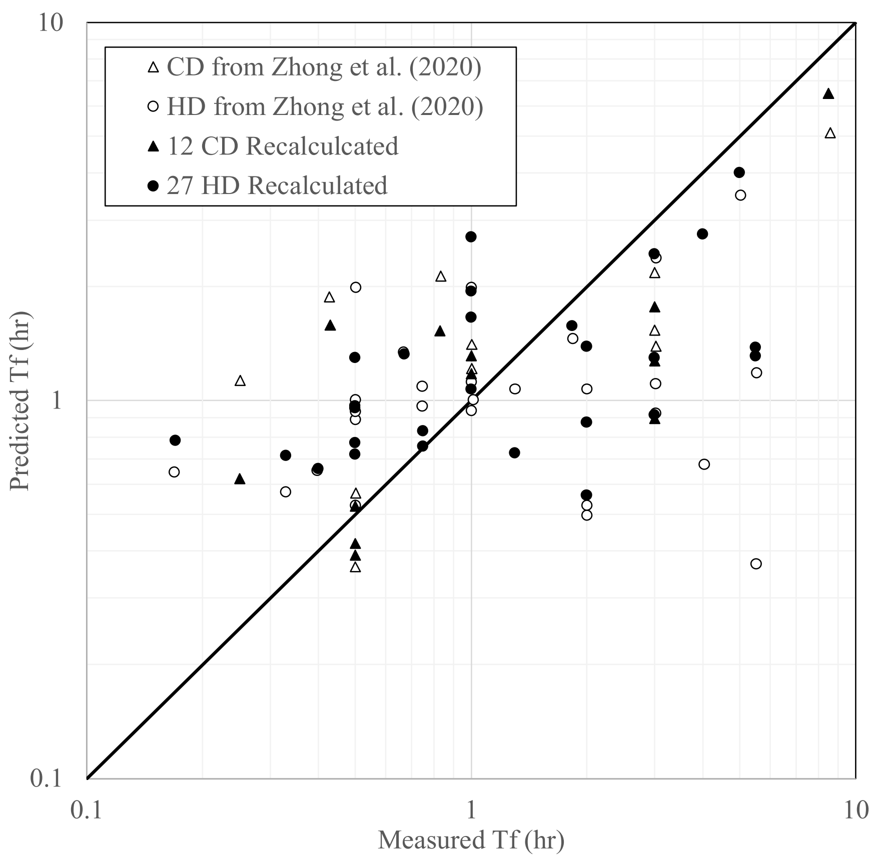

Figure 3 : Comparison of measured and predicted Time failure (Tf) for breached earth-rock dam adapted from Zhong et al. (2020) database.

Recalculated from Zhong et al. (2020) database

Homogeneous dams (HD) :

$$\frac{Q_p}{V_w \cdot g^{\frac{1}{2}} \cdot h_w^{-\frac{1}{2}}} = \left(\frac{V_w^{\frac{1}{3}}}{h_w}\right)^{-1.64} \cdot \left(\frac{h_w}{h_b}\right)^{-1.24} \cdot h_d^{-0.001} \cdot e^{-4.24}$$

Corewall dams (CD) :

$$\frac{Q_p}{V_w \cdot g^{\frac{1}{2}} \cdot h_w^{-\frac{1}{2}}} = \left(\frac{V_w^{\frac{1}{3}}}{h_w}\right)^{-1.37} \cdot \left(\frac{h_w}{h_b}\right)^{-5.68} \cdot h_d^{-0.68} \cdot e^{-2.46}$$

Equations adapted from Bernard-Garcia and Mahdi (2020) database

Homogeneous dams (HD) :

$$\frac{Q_p}{V_w \cdot g^{\frac{1}{2}} \cdot h_w^{-\frac{1}{2}}} = \left(\frac{V_w^{\frac{1}{3}}}{h_w}\right)^{-1.84} \cdot \left(\frac{h_w}{h_b}\right)^{-0.4} \cdot h_d^{-0.4} \cdot e^{-2.35}$$

Corewall dams (CD) :

$$\frac{Q_p}{V_w \cdot g^{\frac{1}{2}} \cdot h_w^{-\frac{1}{2}}} = \left(\frac{V_w^{\frac{1}{3}}}{h_w}\right)^{-1.4} \cdot \left(\frac{h_w}{h_b}\right)^{-5.35} \cdot h_d^{-0.71} \cdot e^{-2.65}$$

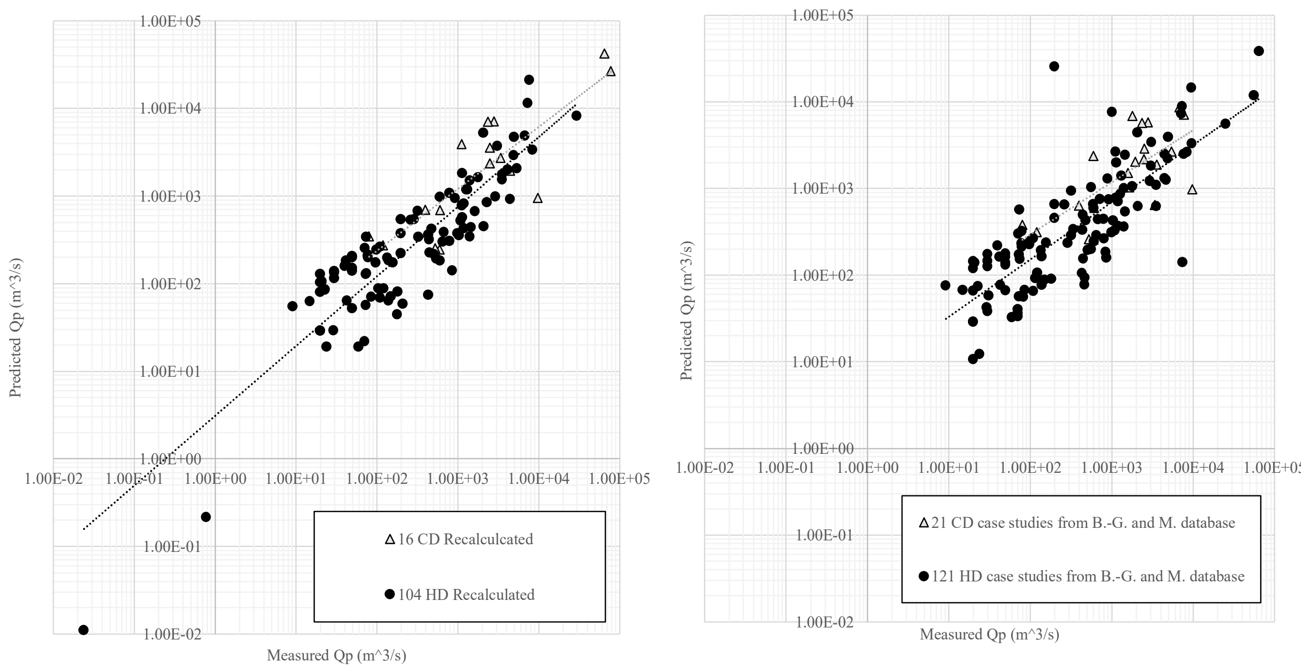

Figure 4 : Comparison of measured and predicted Peak discharge (Qp) for breached earthrock dams adapted from Bernard-Garcia and Mahdi (2020) database

Recalculated from Zhong et al. (2020) database

Homogeneous dams (HD) :

$$\frac{B_{ave}}{H_b} = \left(\frac{V_w^{\frac{1}{3}}}{h_w}\right)^{0.77} \cdot \left(\frac{h_w}{h_b}\right)^{-2.01} \cdot h_d^{0.14} \cdot e^{-0.94}$$

Corewall dams (CD) :

$$\frac{B_{ave}}{H_b} = \left(\frac{V_w^{\frac{1}{3}}}{h_w}\right)^{-0.67} \cdot \left(\frac{h_w}{h_b}\right)^{1.66} \cdot h_d^{-0.08} \cdot e^{-0.12}$$

Equations adapted from Bernard-Garcia and Mahdi (2020) database

Homogeneous dams (HD) :

$$\frac{B_{ave}}{H_b} = \left(\frac{V_w^{\frac{1}{3}}}{h_w}\right)^{0.75} \cdot \left(\frac{h_w}{h_b}\right)^{1.13} \cdot h_d^{0.22} \cdot e^{-1.07}$$

Corewall dams (CD) :

$$\frac{B_{ave}}{H_b} = \left(\frac{V_w^{\frac{1}{3}}}{h_w}\right)^{0.95} \cdot \left(\frac{h_w}{h_b}\right)^{0.9} \cdot h_d^{0.21} \cdot e^{-1.52}$$

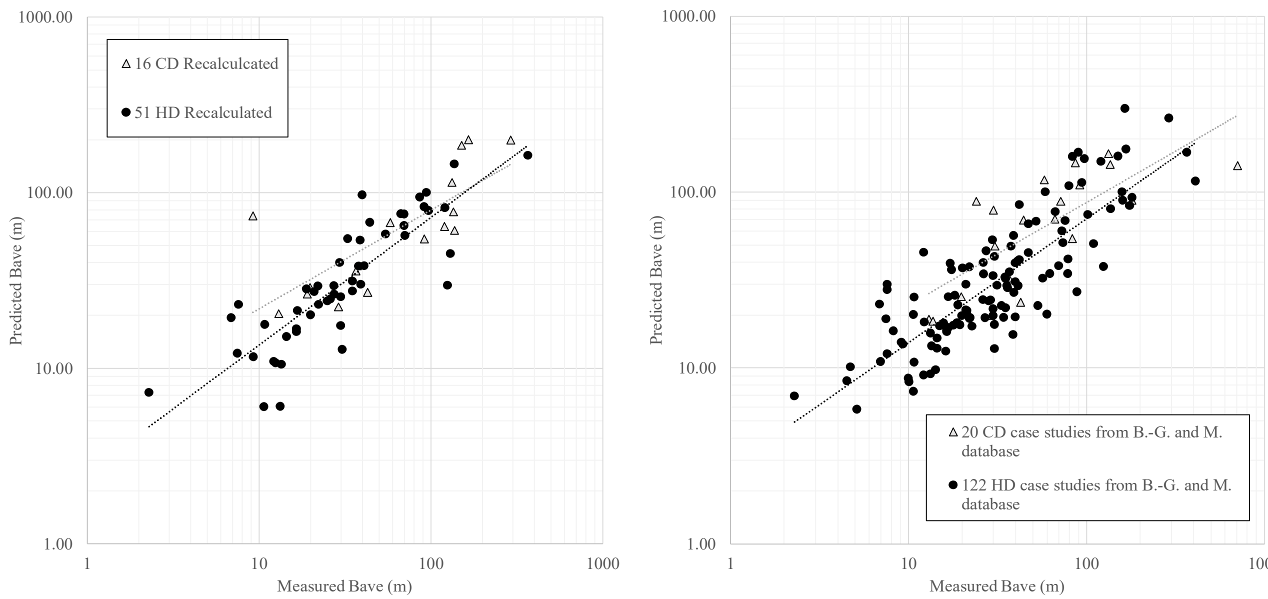

Figure 5 : Comparison of measured and predicted Breach average width (Bave) for breached earth-rock dams adapted from Bernard-Garcia and Mahdi (2020) database.

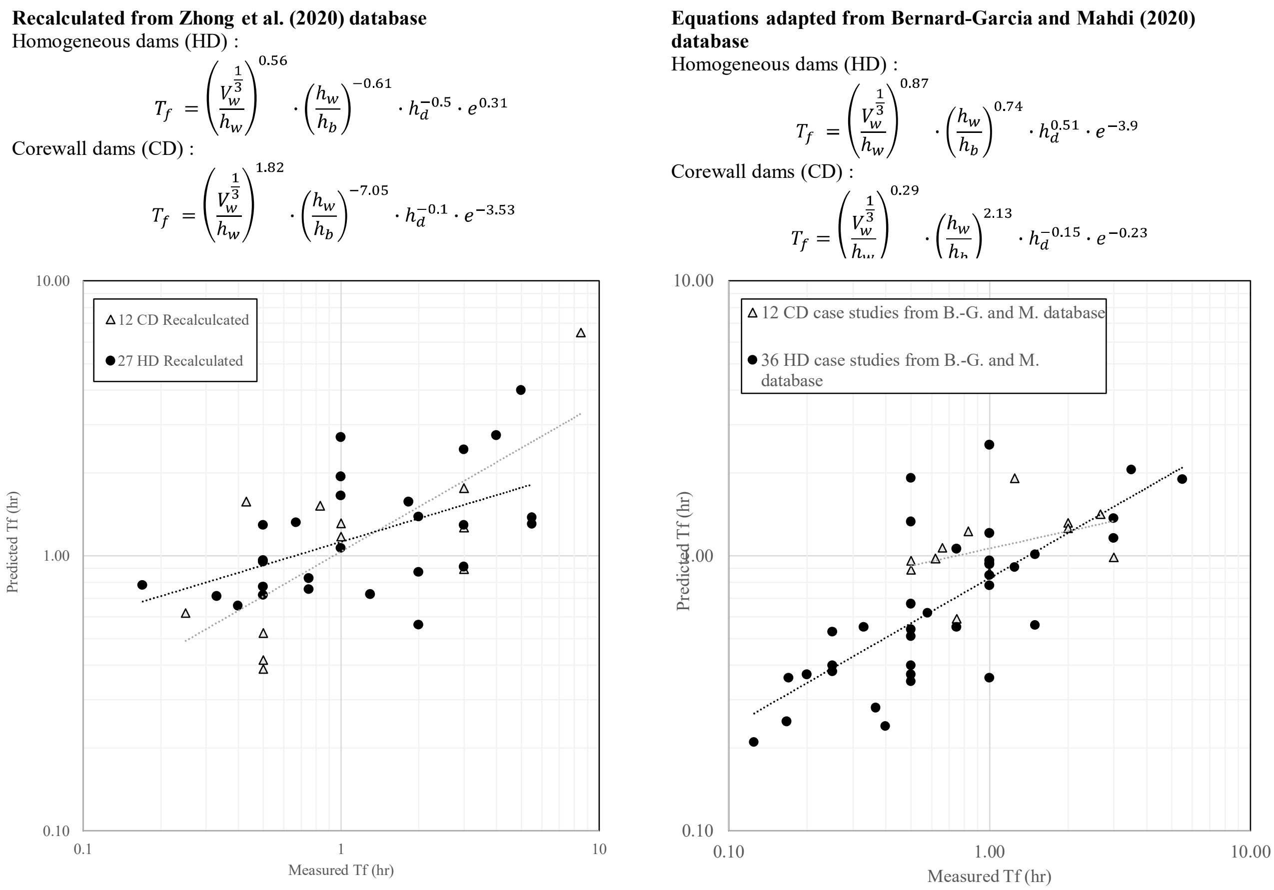

Figure 6 : Comparison of measured and predicted Time failure (Tf) for breached earth-rock dam adapted from Bernard-Garcia and Mahdi (2020) database.

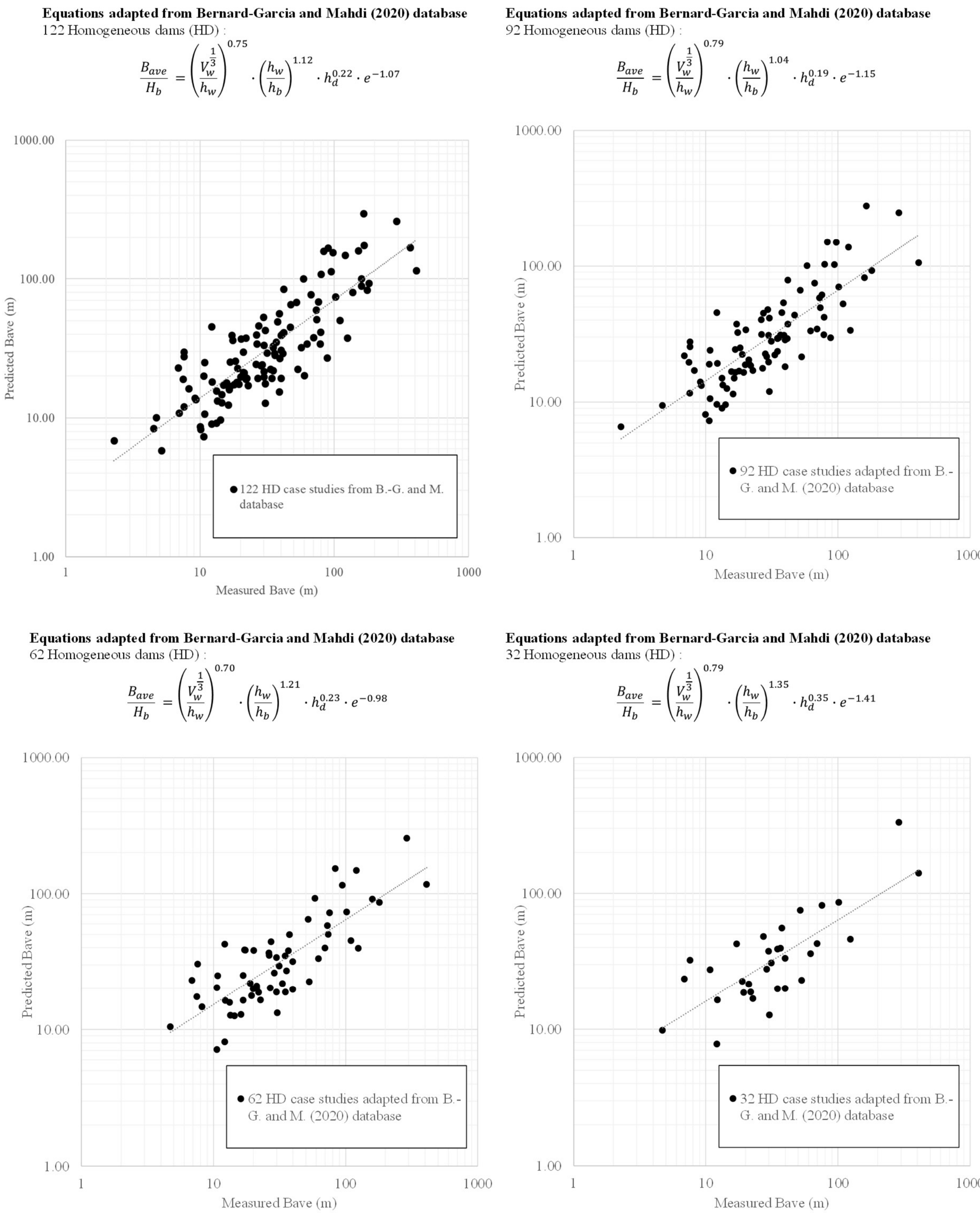

Figure 7 : Comparison of four subsamples measured and predicted Breach average width (Bave) for breached earth-rock dams adapted from Bernard-Garcia and Mahdi (2020) database.